A comparative analysis of Terrestrial and Planetary bow shocks

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Abstract

Collisionless shocks, such as the Earth bow shock, are very spectacular and energetic events in the Universe. For instance, generated by supernovae, stellar winds, and the solar wind collisonless shock have important effects. They are considered to be efficient particle accelerators and they act galactic nebula and therefore they are considered to trigger formation of planetary systems. The Earth's bow shock results from the interaction of the solar wind with the Earth's magnetosphere. Compared to all other shocks wave in the Universe and even our solar system. It is easily accessible by spacecraft, has been studied in detail over the last several decades. It was one of the prime science objectives of many space missions, such as ISEE, AMPTE, Cluster, and Themis. The idea of this short paper is to provide a summary of the talk presented at the conference.

1. Introduction and Overview

The ability that have been provided by space missions to measure fields, ions, and their distributions gave us deep insight into fundamental plasma processes that may occur at other planets under different plasma conditions. We have deep insights into the global dynamics of the Earth's bow shock. How it moves as a response to the dynamic solar wind pressure. Furthermore, newer missions such as Cluster allowed to study in-situ and in detail the physical processes that control particle reflection and acceleration at the Earth's bow shock. According to the theory of diffusive shock acceleration, particles must attain a threshold energy before they can participate in the first-order Fermi acceleration mechanism. Thermal ions must attain the required threshold energy through an 'injection' mechanism that occurs during their initial interaction with the electromagnetic fields at the shock front. Where does the ion injection and reflection occur at the shock? Although, huge progress has been made over the last two decades the identification of the specific injection mechanism remains an outstanding puzzle. The field-aligned ion beams observed at the quasi-perpendicular portion of Earth's bow shock provide detailed information on an injection mechanism operative after a magnetic flux tube first connects to a shock. These beams have been used to remotely sense the local structure of the Earth's bow shock. The observational results confirmed theoretical predictions of the non-stationarity behavior of the shock and the so-called shock ripples. Data and numerical simulations show a clear association between the so-called specularly reflected gyrating ion population, the ion beam population, and the small-scale turbulence in the shock layer. These observations also provide evidence that the solar wind composition can mediate the local shock structure, which then in turn will mediate reflection and acceleration efficiency. A number of processes on different scales (electron and ion scale) conspire to complicate the physics of real shocks.

2. Summary and Conclusions

We now obtained data from Mercury, Venus, Mars, Jupiter, Saturn and even from the heliospheric termination shock. The amount of data, however, is much less than from the Earth's bow shock. Nonetheless, the physical processes at all these collisionless shocks are most likely the same but in the different plasma environment. Processes identified at the Earth's bow shock operate most likely also at other planetary bow shocks. For instance, the process of shock reformation is observed at the termination and the basic features such as shock ramp, overshoot, and upstream waves have been observed by Cassini at the Saturnian bow shock. Since, the Earth's bow shock exists over a wide range of plasma parameters and magnetic field configuration it is our best 'in-house plasma laboratory' that allows us to investigate all these processes in detail. There are similarities and differences of these shocks with respect to the Earth's bow shock, in shape, topology, and solar wind interaction. However, the overall basic features of most planetary shocks are similar to the features observed at the Earth's bow shock.

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